Since the long-term success of the FCVT Program depends on the success of the transportation-related technology development sub-programs of the Hydrogen, Fuel Cells, and Infrastructure Technologies Program (HFCIT), collaborative activities are identified to ensure successful propulsion system/vehicle integration and validation.

4.1 VEHICLE SYSTEMS ANALYSIS AND TESTING

The role of this sub-program is to provide an overarching vehicle systems perspective to the technology R&D sub-programs and activities of DOE's FCVT and HFCIT Programs. As depicted in Figure 14, this sub-program uses analytical and empirical tools to model and simulate potential vehicle systems, validate component performance in a systems context, benchmark emerging technology, and validate computer models. Extensive collaboration with the technology development sub-programs in FCVT, as well as HFCIT, is required in both analysis and testing for this sub-program to be successful. The analytical results of this sub-program are used to estimate the national benefits and/or impacts of DOE-sponsored technology development.

Goals

Use an integrated systems approach to develop, maintain, and employ analytical tools, techniques, and test facilities to benchmark emerging technologies and support the development and validation of DOE-sponsored technologies in a vehicle systems context.

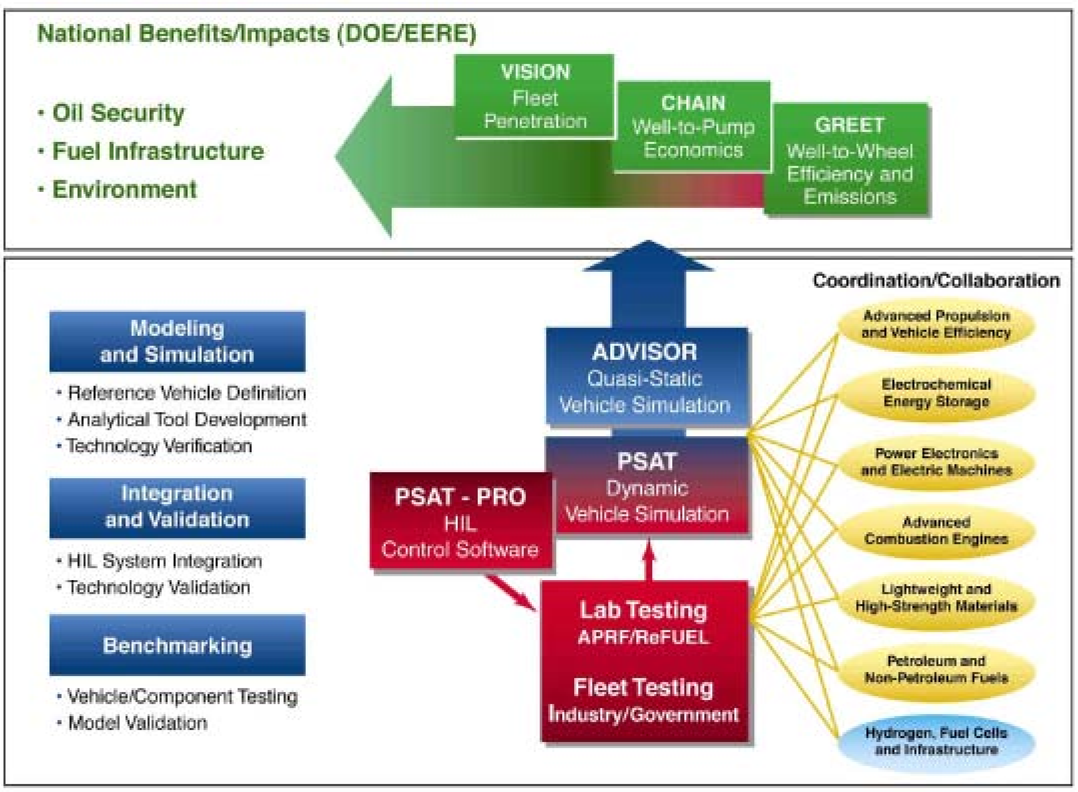


Figure 14. Analytical and empirical tools used to model and validate vehicle components and systems and benchmark emerging technologies.

Programmatic Status

A unique set of tools has been developed and maintained by the Vehicle Systems Analysis and Testing sub-program to support the FCVT Program. The tools depicted in Figure 14 are described in the following paragraphs. VISION, CHAIN, and GREET are used to forecast national-level energy and environmental parameters including oil use, infrastructure economics, and greenhouse gas contributions of new technologies, based on FCVT vehicle-level simulations that predict fuel economy and emissions using ADVISOR or PSAT. Dynamic simulation models (i.e., PSAT) are combined with DOE's specialized equipment and facilities to validate DOE-sponsored technologies in a vehicle context (i.e., PSAT-PRO control code and real components in a virtual vehicle test environment). The Advanced Powertrain Research Facility (APRF) and the Renewable Fuels and Lubricants Facility (ReFUEL) are used to test light-/medium- and heavy-duty vehicles (operating on a variety of liquid and gaseous fuels), propulsion systems, and components in controlled environments to acquire scientific data. Fleet tests are used to assess the functionality of technology in the less-predictable real-world environment. Modeling and testing tasks are closely coordinated to enhance and validate models as well as ensure that test procedures and protocols comprehend the needs of coming technologies.

ADVISOR (ADvanced Vehicle SimulatOR) is used to understand trends and preliminary vehicle design through quasi-static analysis of component performance and efficiency characteristics to estimate fuel economy. Vehicle power demand on the road is used to calculate the demand on propulsion system components and their resulting characteristics each second (using static component map data); these values are summed to produce overall results for a driving cycle (commonly referred to as "backward-facing" simulation). This architecture is suitable for quick evaluation of multiple scenarios due to fast runs. Capabilities include component selection and sizing (conventional, hybrid, and hybrid fuel cell vehicles), energy management strategies, optimization, and target development.

PSAT (Powertrain Systems Analysis Toolkit) allows dynamic analysis of vehicle performance and efficiency to support detailed design, hardware development, and validation. A driver model attempts to follow a driving cycle, sending a power demand to the vehicle controller which, in turn, sends a demand to the propulsion components (commonly referred to as "forward-facing" simulation). Dynamic component models react to the demand (using transient equation-based models) and feed back their status to the controller, and the process iterates on a sub-second basis to achieve the desired result (similar to the operation of a real vehicle). The forward architecture is suitable for detailed analysis of vehicles/propulsion systems, and the realistic command-control-feedback capability is directly translatable to PSAT-PRO control software for testing in the laboratory. Capabilities include transient performance, efficiency and emissions (conventional, hybrid, and hybrid fuel cell vehicles), optimization of control strategies, and identification of transient control requirements.

PSAT-PRO (PSAT rapid control PROtotyping software) allows dynamic control of components and subsystems in hardware-in-the-loop (HIL) testing. Real components are controlled in an emulated vehicle environment (i.e., a controlled dynamometer and driveline components) according to the control strategy, control signals, and feedback of the components and vehicle as determined using PSAT. The combination of PSAT-PRO and HIL is suitable for propulsion system integration and control system development as well as rigorous validation of control strategies, components, or subsystems in a vehicle context (without building a vehicle). Capabilities include transient component, subsystem, and dynamometer control with hardware operational safeguards compatible with standard control systems.

Laboratory testing applies state-of-the-art facilities to support the development of detailed technology integration requirements; validate DOE-sponsored technologies; and measure, within a vehicle systems context, progress toward FCVT technical targets. In addition, lab tests benchmark components and vehicles to validate models, support technical target setting, and provide data to help guide technology development tasks

Operational and fleet testing evaluates vehicles in real-world applications to measure progress toward FCVT technical targets and disseminate accurate, unbiased information to potential vehicle users, DOE, industry technology developers, and vehicle modeling tasks. The scope includes vehicles that use DOE-sponsored technology or technologies of particular interest to FCVT (i.e., hybrids and internal combustion engine vehicles fueled with hydrogen and other gaseous/ liquid fuels), as well as the related fueling infrastructure. Capabilities include measuring performance, costs, fuel consumption, in-use maintenance requirements, and operational characteristics. The execution of these tasks occurs under cost-shared agreements with industrial partners such as electric utilities and automotive companies. Test sites may include utility or government locations where fleet vehicles are used and maintained. National laboratories provide data acquisition, analysis, reporting, and management support.

Approach

Vehicle Systems Analysis and Testing will develop, maintain, and use advanced analytical tools, techniques, and test facilities to (1) provide guidance to the technology development sub-programs and (2) validate the performance of DOE-sponsored technologies in the context of complete vehicle systems.

Task Descriptions

The activities and associated tasks are described in the following paragraphs. Each activity will involve extensive coordination and/or collaboration with the FCVT Program technology development sub-programs and those HFCIT Program sub-programs that address transportation technology.

Modeling and Simulation

Reference vehicle definition—Develop attributes and specifications for a portfolio of hypothetical “reference vehicles” that represent the spectrum of vehicles addressed by the FCVT and HFCIT programs.

Analytical tool development—Develop and maintain computer models and analytical tools that will enable simulation of the component technologies and reference vehicles. The tools will comprehend the technology development direction, as well as the needs of the industry partners, of both FCVT and HFCIT.

Technology verification—Incorporate component and subsystem models in the reference vehicles and conduct vehicle simulations to ensure compatibility with potential propulsion/vehicle configurations.

Integration and Validation

HIL system integration—Integrate and test DOE-sponsored experimental component/subsystem hardware in an emulated vehicle environment with realistic control system interfaces and interactions. PSAT-PRO will be used to optimize propulsion system control, leading to refined performance and control requirements to feed back to DOE technology developers and industry partners.

Technology validation—Validate, within a vehicle systems context, that the technologies developed by the FCVT and HFCIT programs meet their technical targets and are suitable for vehicle applications.

Benchmarking

Vehicle/component testing—Test and analyze emerging technologies obtained from worldwide sources other than the FCVT and HFCIT programs, using laboratory facilities and field testing. The results will be distributed to DOE and industry partners to support (re)assessment of the content and targets of R&D sub-programs.

Model validation—Use test data to validate the accuracy of the vehicle and component computer models, including overall measures (e.g., fuel economy and state-of-charge of energy storage devices over a driving cycle) as well as transient component behavior (e.g., fuel rate and torque).

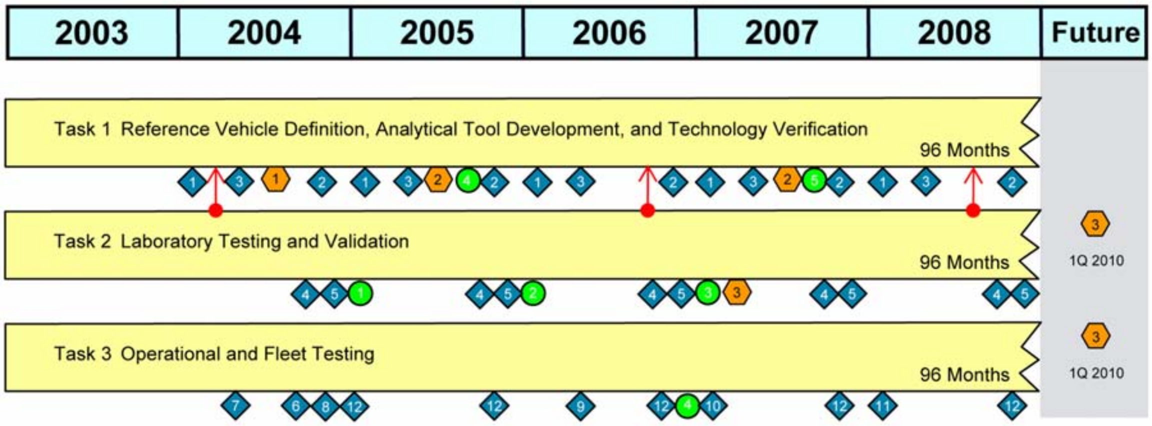
Vehicle Systems Analysis and Testing is a support sub-program conducted on a continuous basis, with software and hardware tasks refined annually, as shown in Table 1.

Table 1. Tasks for Vehicle Systems Analysis and Testing

Task	Title	Duration
1a	Reference Vehicle Definition	1 month (per annum)
1b	Analytical Tool Development	96 months (with annual updates)
1c	Technology Verification	As required (i.e., new initiatives or technology introductions)
2a	HIL System Integration	96 months (revised annually)
2b	Technology Validation	96 months (revised annually)
3a	Vehicle/Component Testing	96 months (revised annually)
3b	Model Validation	96 months (revised annually)

Milestones

Milestones cannot be precisely defined because this sub-program is dependent on the availability of data/models and experimental hardware from other FCVT and HFCIT technology development sub-programs, as well as the availability of technologies from worldwide sources. Therefore, the milestone schedule reflects annual updates and is subject to annual revision. Milestones for Vehicle Systems Analysis and Testing are shown in the following network chart.



Legend

Milestone

1. Specification of representative vehicle platforms
2. Simulation software release
3. Verification of DOE-sponsored technologies
4. HIL system integration and hardware studies
5. DOE-sponsored component validation
6. MY04 Toyota Prius benchmarking
7. Hydrogen/highly compressed natural gas vehicle testing
8. Orion compressed natural gas/electric hybrid bus testing
9. Technical and economic evaluation of advanced propulsion system Hydrogen Fueling Pilot Plant
10. Hybrid electric transit bus testing
11. Hydrogen fuel cell vehicle testing
12. Model validation

Technology Program Output

1. Technical targets for advanced technology components and subsystems
2. Revised targets for advanced technology components and subsystems
3. Validated technologies to industry

Supporting Input

1. Light Vehicle propulsion subsystem components for vehicle—level integration and testing using HIL
2. Semiconductor motor-controller for validation
3. 42V/12V DC-DC converter for validation
4. Fuel cell subsystem for integration and testing in 5 kW APU
5. Engine + aftertreatment R&D results from Combustion and Emission Control R&D